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Analysis on simulation modeling of automobile vibration and ride performance

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ABSTRACT

With the rapid development of science and technology, the automobile industry is booming as well. With the application of high-tech technology in automobile industry, people can basically be satisfied with their performance. While, nowadays, more attention are focused on the ride performance which will directly affect the comfort and safety when driving or riding. This paper is focused on the study of vehicle ride performance. Based on the actual vehicles, a new kind of vibration simulation model which is convenient to operate is designed. By using the model to analyze the vehicle ride performance, a more real simulation effect can be achieved. First of all, this study established a quarter two-freedom model of vehicle and accordingly selected the Macpherson front suspension from Santana 2000 Gsi saloon car as the target. Basic parameters of the simulation model contain the suspension stiffness, damping coefficient of shock absorber and the road excitation. The first two parameters can be calculated while the road surface excitation is gained by using white noise integral method. By inputting the calculated basic parameters into suspension vibration system of simulation model, we can get the car ride performance result which turn out that the model is effective and feasible. Besides, the parameter adjustment can make the vibration characteristics of the images and data more intuitive, which further laid the basis of accurate control research.

KEYWORDS

Ride performance; Simulation model; Road excitation.

INTRODUCTION

Along with the development of economy, the industry also showed a rapid development momentum. As one of the main transport tools, cars have entered innumerable families. Since the year of 2009, the whole sale of cars ranked among the highest for five consecutive years and even reached twenty million in 2013. Although the total number ranked at the top, statistics show that household car ownership per capita in China at present reached 45 vehicles per one thousand people, which is under the world average level, let alone compared with the developed countries. Therefore, the automobile industry in China has great potential for development. In order to seize the great period of development and make differences, we have to pay more attention on developing our own brands by resorting to strong technology support to improve the performance and quality of the car, strengthening the industry of independent automobile brand[1].

With the development of the economy, infrastructures have been building constantly, especially the high grade highway. When car ownership increases sharply, the car mileage or car driving time is increasingly longer. Gradually, people’s corresponding requirements on the performance of car become higher. When improving the performance of car, we cast more attention on car ride performance[2]. In the process of driving, the car affected by road roughness will produce vibration which may also be caused by the car itself. The faster of the speed is, the greater of the vibration will become. While the vibration can not only accelerate the abrasion of auto parts, but also create harmful influence to the driver, for example, physiological reactions will bring danger to the driving. If we choose to slow down to relieve the vibration, not only will reduce the transportation, but also will improve the efficiency, influencing the discharge of cars. Therefore, the study of ride performance is of great significance in developing the cars, for the ride performance not only relates to the ride performance, also relates to the comfort of crew in the car. The improvement of vehicle ride performance can improve ride comfort; reduce the wastage of the auto parts in the case of a high speed; make driving safer; make the car transport efficiency, achieving fuel economy at the same time[3]. According to the above, many automobile research and development departments nowadays take drive comfort as an important subject. In order to promote the quality of the car, car ride performance test has become a common study.

VEHICLE RIDE PERFORMANCE

Research content

Vehicle ride performance mainly studies two aspects: influence of pavement roughness degree on passenger comfort degree and vibration influence on the car itself. When the car runs in the input surface (including random input and pulse input), each way can cause vehicle vibration by influence of pavement roughness. It passed into the body of the car through the tire, suspension and felt by the occupant, causing physiological reactions from passengers, uncomfortable or fatigue[4]. According to the degree of such uncomfortable, the driver can adjust the speed to reduce the vibration. In a practical sense, the study of car ride performance equals to the study of road - car - people system which is dynamic. Figure 1 is the representation of the vibration system. As shown in the figure, the system is composed of four parts: vehicle system input; vibration system; vehicle system output and result evaluation index[5]. The whole car system is complex; we cannot limit our research on this. The study not only has to achieve the purpose of improving comfort, but also ensure the stability and security of the driving car, avoid the phenomenon ”find-it and fix-it mentality”.

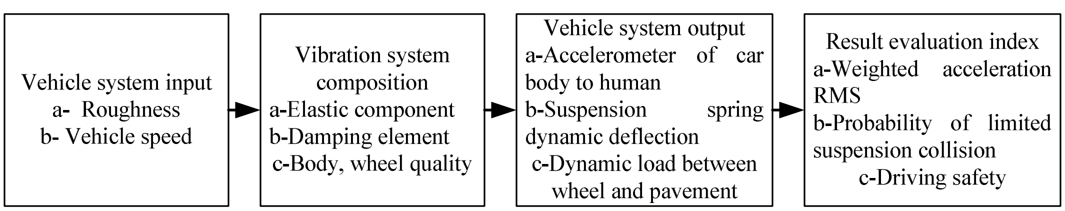

Figure 1 : “road-vehicle-people” vibration system

Research methods

The automotive industry continues to progress. In the automotive industry, in order to meet the growing number of new requirements for vehicle operation, high-tech technology with technical content has gradually been applied; with the tireless efforts of automotive research and development personnel, a lot of research achievement has been made on ride performance[6].

Currently, the main methods on vehicle ride performance are experimental methods and theoretical methods. Experiment research methods need real models to participate, using vehicles for various tests. Theoretical approach is based on computer technology and relied on mathematical modeling thought. According to the multi-body dynamics, virtual simulation model can be build to simulate on the road excitation signal, after obtaining the experimental data through the output of the corresponding experimental parameters, evaluation index will be gained by statistical processing. Then researchers can analyze evaluation index to make relevant evaluation. There are three test methods in experiment research methods, including outdoor road test, proving ground test and indoor simulation text. At present, experiment research methods are used widely in foreign countries. In China, only some of the larger auto manufacturing companies and research institutions were conditional; since the experiment research methods have restrictions for testing equipment, grounds and vehicles, it also limits the research on ride performance by texting methods. On the other hand, theoretical research methods have widespread applications both in China and foreign countries; especially in the last decade, research achievements on ride performance in China are relatively rich and developing fast[7]. Compared to experiment research methods, this methods have lower cost. And the site and climate cannot influent the study progress. This study shows the vehicle ride performance research methods diagrammatic drawing, as shown in Figure 2.

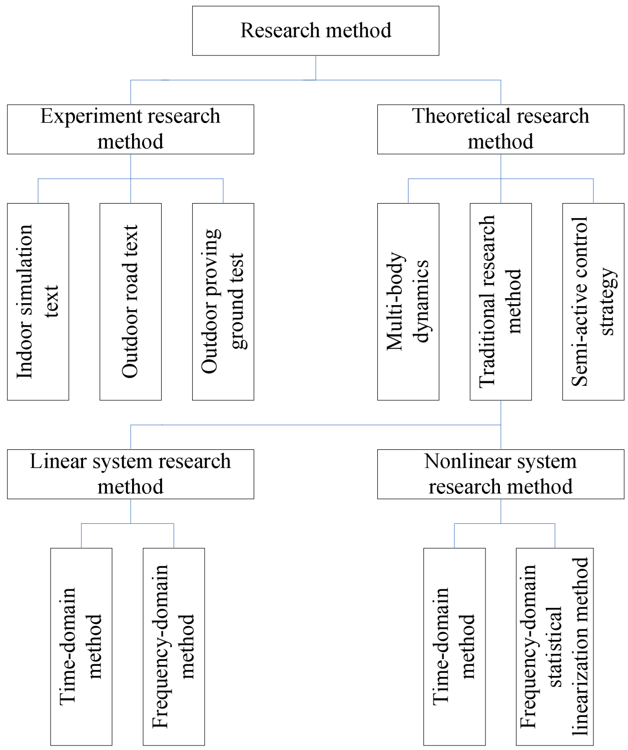

Figure 2 : Vehicle ride performance research methods diagram

SIMULATION MODEL

Construction of simulation model

Vehicle ride performance can be evaluated by the research on vibration performance of the suspension system. The direct influencing factors include structural parameters of road roughness, speed and suspension. Fourier analysis methods are commonly used in the former research on vehicle ride performance; when using this method, the first thing is to deduce the vehicle vibration system and frequency response characteristic of vibration response. The second thing is to calculate weighted root mean square acceleration, including all three coordinate axes. This study only analyzed the weighted root mean square acceleration of vertical direction, using simulate model to analyze vehicle ride performance. The research content is the study procedure of suspension vibration simulation model shortening the development circle of suspension design and simplifying suspension vibration. And the internal and external parameters are independent and can be independently adjusted simply and quickly, obtaining reliable results. This study selected 2000Gsi Santana sedan, analyzed vibration characteristics of suspension by analyzing various parameters, evaluated whether this model of car can meet the basic requirements of ride performance by output results, meanwhile verifying the usability of designed model.

Model principles and parameters

In the mechanical model, spring indicating the relationship between force and displacement is often seen as having linear elasticity but with no quality; damper representing the relationship between force and velocity is seen as having linear damping coefficient and no quality; quality representing the relationship between force and acceleration is usually seen as absolutely rigid body. According to the above description, front wheel vibration system in one side of vehicle can be simplified, as shown in Figure 3.

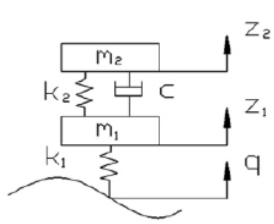

Figure 3 : Vehicle unilateral front wheel vibration system

In the suspension system, the influencing parameters describing vibration frequency response characteristic include suspension stiffness and damping coefficient of shock absorber. The Santana car this study selected is an economical and practical model of cars, and its related parameters are as shown in TABLE 1.

TABLE 1 : Main suspension parameters of Santana 2000Gsi sedan

Name	Parameters
Axle load of full-load aft shaft	810kg
Total mass of both-side suspension in front axle	84kg
Front wheel quality	18.5kg
Tire stiffness k_1	194kN.m^{-1}
Spring stiffness k_3	22.68kN.m^{-1}

Damping coefficient of suspension stiffness and shock absorbers can be calculated from the empirical formula. According to these two parameters obtained from calculation, vibration characteristics of the suspension can be simulated roughly, obtaining result from preliminary analysis.

Suspension vibration simulation model

To analyze the dynamic characteristics of the suspension in the time domain, the performance of pavement roughness in frequency domain needs to be transformed into the time series in the time domain. The theory that finite bandwidth white noise produces excitation signal can be used to describe the driving pavement situation. These two have similarity, therefore the input resource of simulation model can select finite bandwidth white noise to simulate; simulate driving pavement can be achieved by integrating input resource.

In this study, matlab software is used to construct white noise road excitation model; SIMULINK toolbox in this software can be used to build the model. The model diagram is as shown in Figure 4. The established model can input the road excitation information produced by simulation in the suspension vibration system.

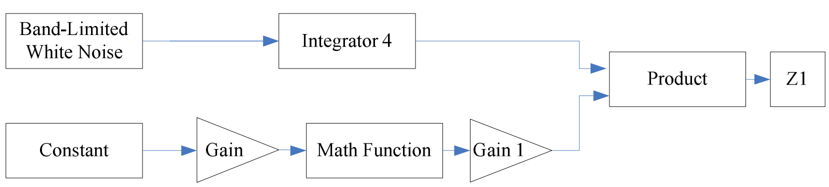

Figure 4 : Finite bandwidth white noise road excitation model

According to inspection standard of human body's bearing capacity on vibration and ride performance, the evaluation of vehicle ride performance can be evaluated in three axes of the seat surface, respectively x, y, z direction. When researchers evaluate long-time random vibration's influence on human body, the evaluation criteria of human body's bearing capacity can be consistent with subjective sensation. In addition, in the vehicle driving environment, the evaluation result of the relationship between subjective sensation and multi-input point and multiaxial vibration environment also accord with subjective sensation. Normally, with the premise of not affecting precision, the description of ride performance in the vertical direction affects comfort most. This study selected B-level road with the roughness coefficient of 64X10-6, with speed limit of 80 kilometers per hour, from vibration of vehicle displacement in the vertical direction, vibration acceleration, displacement, acceleration, and acceleration RMS can be obtained after second derivative, as shown in Figure 5, Figure 6 and Figure 7.

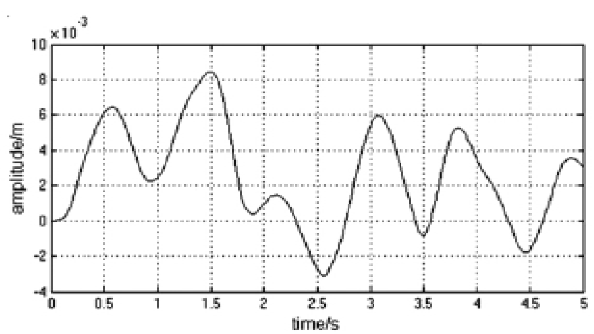

Figure 5 : Vehicle body displacements in vertical dimension

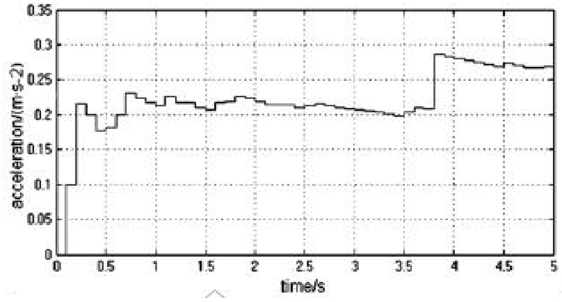

Figure 6 : Vibration acceleration in vertical dimension

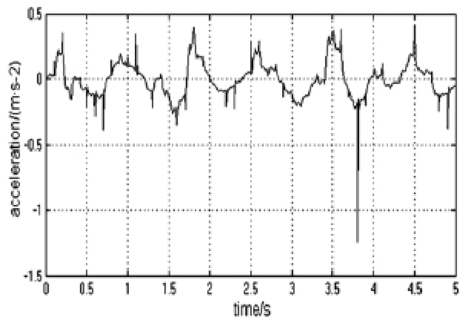

Figure 7 : Acceleration RMS in vertical dimension

In the parameter setting of vehicle, the front wheel quality is 18.5, with kilogram as unit. Unilateral suspension unit is also kilogram, the value is set to 363; tire stiffness and suspension rate unit is Nm; values for 194000 and 22230; reference spatial frequency is constant 0.1; damping coefficient of shock absorber is 1570. After the coefficient setting, select the common pavement grade and common speed for separate simulation. About vertical displacement of different simulation results, vibration acceleration in vertical dimension and acceleration RMS in vertical dimension, no further discuss will be listed here; the article only gives the simulation operation result.

TABLE 2 : Common pavement grade and acceleration RMS in vertical dimension under speed

Speed /km.h^{-1}	Acceleration RMS /m.s^{-2}	
	B-level pavement	C-level pavement
20	0.1343	0.2657
40	0.1885	0.3742
60	0.2497	0.4567
80	0.2666	0.5260

RESULT ANALYSIS

In the ride performance evaluation of simulation result, the adopt standard is ISO 2631-1; evaluation result is shown in TABLE 3. Comparison of the data in TABLE 2 and TABLE 3 shows that, when Santana sedan of the fixed model is driving in the common grade road in common speed, state of the occupant mostly are a "no uncomfortable"; some passengers are “a little uncomfortable”. These results can be obtained intuitively, which shows that the model car can basically meet the requirements of the human body in terms of ride comfort. Therefore this type of car is in accordance with the ride performance requirements.

TABLE 3 : Subjective feeling of passengers and acceleration RMS corresponding table

Acceleration RM /m.s^{-2}	Subjective feeling
<0.315	No uncomfortable
0.315-0.63	A little uncomfortable
0.5-1.0	Quite uncomfortable
0.8-1.6	Uncomfortable
1.25-2.5	Very uncomfortable
>2.0	Extremely uncomfortable

Two-freedom suspension vibration simulation model designed in this study is constructed by using the MATLAB software; the SIMULINK toolbox in the software is capable for model framework. After the modeling is completed, pick out the parameters affecting the vibration characteristics of the suspension; input of these key parameters in the model, and then pick out the common grade road and the usual driving speed. By simulating grade road and driving speed separately without inform, we can achieve simulation results of ride performance. Conduct riding evaluation on the results according to ISO 2631-1 standard, the rational conclusion on suspension structure can be achieved subjectively from comparison results.

CONCLUSION

Automotive industry continues to develop, which makes that vehicle ride performance increasingly concerned by people. In the term of driving and riding vehicle, ride performance directly affects the comfort and safety. This article focused on the study of vehicle ride performance. Based on the actual vehicles, the new kind of vibration simulation model designed in this article is convenient to operate. By using the model to analyze the vehicle ride performance, a more real simulation effect can be achieved.

First, this study established a 1/4 two- freedom vehicle model, and selected the car instance on the basis of the model. The automobile front suspension shall have mature technology, so Santana 2000Gsi car is selected as the test object. The basic parameters of the simulation model include suspension stiffness, damping coefficient of shock absorbers and road excitation; the first two parameters can be calculated, and road excitation is generated by the white noise integral method. Inputting these basic parameters to the simulation model of suspension vibration system, ride performance can be obtained from comparative study. On the premise that each parameter setting is invariant, inspect ride comfort by separately changing pavement grade and common speed. Eventually the research come to conclusion that whether the vehicles ride performance can meet the passenger needs by simulating the results. In addition, the simulation model parameters can be adjusted so that the image and data with vibration characteristics can be displayed more intuitively, further laying the precise controlled research foundation.

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